

UNCLASSIFIED

AD 295 170

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

63-2-3

295170
295170

CATALOGED BY ASTIA
AS AD NO. _____

ANNUAL PROGRESS REPORT

1 February 1962 to 31 January 1963

John T. Hammack, Principal Investigator

AN EXPERIMENTAL ANALYSIS OF BEHAVIOR DURING SLEEP

Contract Number DA-49-193-MD-2180

ASTIA

Qualified requestors may obtain copies of this report from ASTIA

A B S T R A C T

1. **Preparing Institution:** The Washington School of Psychiatry
2. **Title of Report:** An Experimental Analysis of Behavior During Sleep
3. **Principal Investigator:** John T. Hammack
4. **Number of pages and date:** 6 pages, January 31, 1963
5. **Contract Number:** DA-49-193-MD-2180
6. **Supported by:** U. S. Army Medical Research and Development Command
Department of the Army
Washington 25, D. C.

This report is the second in a series of studies concerned with the nature of sleep as a behavioral and physiological state. Operant conditioning techniques and continuous measurement were used to produce and control behavior in sleeping adults, and to permit recording of behavioral and physiological data in individual subjects over extended periods.

NOTE: Copies of this report are filed with the Armed Services Technical Information Agency, Arlington Hall Station, Arlington 12, Virginia, and may be obtained from that agency by qualified investigators working under Government contract.

This report is the second in a series of studies concerned with the nature of sleep as a behavioral and physiological state. Operant conditioning techniques and continuous measurement were used to produce and control behavior in sleeping adults, and to permit recording of behavioral and physiological data in individual subjects over extended periods.

Experiment 1. Behavioral Responsiveness During EEG Sleep.

This experiment studied the effects of two conditions of reinforcement on behavioral responding during natural sleep. Condition 1 consisted of the simple instruction to respond by closing a microswitch taped in the right hand every time a thirty-five decibel (referenced to waking threshold) tone was presented through an ear receiver taped in the preferred ear. After a night of sleep under this condition the subject was given general information on his performance, and prior to each succeeding session he was encouraged to try to improve his responding. In condition 2 the subject was instructed that if he failed to respond to the tone within four seconds he would be awakened abruptly. After a baseline period of one or two nights, condition 1 was instituted for three to five nights. Following this, the subject was under condition 2 for three nights. The nights of sleep lasted for about six hours during which brain potentials were continuously monitored with the EEG. A finger plethysmograph was used for continuous monitoring of finger pulse volume. The tone, lasting four seconds, was presented every two minutes throughout the night. The awakening stimulus used in condition 2 consisted of a graduated series of intense stimuli, beginning with a fire alarm and including a bright flashing light and shocks to the leg. All stimulation was terminated by closure of the microswitch.

The following results were obtained: (a) Performance of this simple task was a function of depth of sleep. During the low voltage, lighter stages of sleep, the subjects responded correctly on fifty to ninety percent of the stimulus occasions. During the deep, high voltage stages of sleep the percentage of correct responses was very small. (b) Under condition 1 the percentage of responses during stage 1 REM (the so-called "dreaming" stage) was essentially zero. However, under condition 2, three out of four subjects showed a marked increase in correct responses during stage 1 REM. These data contribute some evidence to the question of whether stage 1 REM is a light or deep stage of sleep. Traditionally it has been considered a light stage because the EEG shows low voltage, fast frequencies, but several investigators have found that it is difficult to arouse a subject in this stage. The present results imply that the "dreaming" phase is indeed a highly activated stage but that the subject is not attentive to external stimuli unless the stimulus is given the properties of a warning signal. The subject then responds as readily in this stage as in other phases of light sleep. (c) Under both conditions of reinforcement the proportion of correct responses in any stage of sleep declined through the night as well as on successive nights. Condition 2 reduced somewhat the slope of this decline but did not eliminate it. These findings indicate that while the EEG stage of sleep accounts for part of the variability in

responsiveness, it cannot account for all of it. Other physiological factors must be operating, so that a given stage of sleep does not have consistent properties throughout the night. The results also show that under condition 2 regular negative reinforcement is not sufficient to sustain performance either within or between nights of sleep. Whether performance can be sustained by changes in the reinforcement parameters remains an important question to be investigated.

Experiment 2. Auditory Discrimination During Sleep.

This study examined the effects of two conditions of reinforcement on a simple auditory discrimination task. The procedures were the same as those described in Experiment 1 except that there were two tones of equal intensity but different frequency (1200 and 800 cps). The results were as follows: (a) Discrimination occurred both in condition 1 and condition 2, but improved greatly in condition 2. (b) The ordinal probability of correct responding in Stage 1 REM was increased under condition 2. (c) Correct responses declined as a function of time of night and of successive nights of stimulation. It appears that subjects adapt quickly to a given level of negative reinforcement, and no method for preventing this habituation has been found.

Experiment 3. Finger Pulse Rate Changes During Sleep.

To investigate the observed decline in behavioral responsiveness through the night (Experiment 1) another physiological factor, pulse rate, was studied. Using a finger plethysmograph for continuous monitoring, the pulse rate of eight subjects was measured during four successive nights of normal sleep. No external stimulation was presented on any night. Analysis of the data obtained from three of the eight subjects indicated: (a) that there was a slight overall decline in pulse rate through the night with perhaps a recovery beginning prior to full awakening; (b) that the mean rate and the variability of the pulse rate were consistently greater in stage 1 REM than in stages 2, 3, or 4 (which were approximately equal), yet were slightly less than in stage 1 A, or when fully awake; (c) that pulse rate tended to increase gradually prior to each occurrence of stage 1 REM, reach a peak during stage 1 REM, and then decline after termination of each period of stage 1 REM; (d) that the higher rate observed during stage 1 REM was not simply the result of body movements (brief arousals) occurring prior to or during stage 1 REM. Because of the greater variability of the pulse rate during stage 1 REM, analysis of the data of all eight subjects will also include an intra-stage comparison of the pulse rate during and between actual bursts or rapid eye movements.

In regard to the findings of Experiment 1, these data furnish additional evidence in support of the view that the "dreaming" phase, or stage 1 REM, is a highly activated stage of sleep. Moreover, the results from both of these experiments, as well as the findings of Hawkins, et al. (3) that basal skin resistance increases in stage 1 REM, support the conclusion that

stage 1 REM represents a neurophysiologically unique phase of sleep.

Experiment 4. Discrimination of EEG Sleep Stages.

Discrimination of EEG sleep stages has been studied in two subjects in the following manner. On night 1 the first subject was given several hours of training with an operant behavior procedure known to be capable of producing performance during sleep without EEG signs of waking (1). On night 2 the subject was told that a soft tone (1500 cps) would sound continuously each time he exhibited a particular pattern of brain activity (sleep stage 1 REM), and that on the following two nights he would be asked to respond on his microswitches whenever he exhibited that same brain activity, although the tone would not be present. The subject did not respond on nights 3 and 4.

A second subject was given two nights of training to respond without awakening, followed by two nights during which the tone was continuously correlated with each occurrence of stage 1 REM. On night 4 the subject was given additional instructions to respond periodically during the occurrence of the tone, so that the experimenter would know that he heard it. The subject responded on four separate occasions during night 4, and in the last three instances responding began within two seconds of the onset of the tone. However, EEG signs of waking were present during all four occasions. The tone was not presented during the fifth night, and the subject failed to respond.

The results of Experiment 1, which were unavailable when these subjects were studied, show clearly that verbal instructions alone are not sufficient to produce responding in stage 1 REM. Therefore, even though the subjects may have been able to discriminate this stage of sleep, it is not surprising that they failed to respond during it. Further investigation will employ aversive consequences, similar to those used in Experiment 1, for failure to respond during this sleep stage.

Experiment 5. Acquisition and Control of Operant Behavior During Sleep.

A total of twenty subjects have now been studied in an effort to establish conditions that will permit learning to take place during EEG sleep. In a previous report (2) it was suggested that a detailed analysis of the data of each subject who learned to respond to the tone would reveal that a frequency rhythm similar to that of the alpha rhythm had appeared in the record during at least one presentation of the tone. Subsequent analysis has confirmed this, and to date no technique has been found to prevent all occurrences of the alpha-like rhythm. We have not been able to determine whether or not it is actually the alpha rhythm. It lasts less than one second usually, is accompanied by a general increase in the background EEG voltage, and always appears to be slightly faster in frequency than the subject's normal waking alpha rhythm. It appears to have a frequency about 1 to 2 cycles per second above a subject's alpha

rhythm and about 1 to 2 cycles per second below the frequency of his sleep spindles.

In support of the view that it is a "distorted" spindle (caused by the general voltage increase) may be the fact that each presentation of the tone is made contingent upon the occurrence of a sleep spindle (in order to verify EEG sleep). The tone could be presented only during the high voltage, slow stage of sleep (stage 4) where spindles are either absent or cannot be detected visually. This possibility has not yet been explored experimentally, because a subject usually will not remain in stage 4 or return to it when stimulation is being presented periodically. Thus the tone could only be presented rather infrequently during each nightly session.

Although the occurrence of an alpha-like rhythm presents a major problem in the investigation of whether or not learning is possible during EEG sleep, it should not be permitted to obscure the fact that a relatively simple form of learning did occur under conditions considerably more restrictive than those that normally prevail in the waking state.

REFERENCES

1. Granda, A. M., & Hammack, J. T. Operant behavior during sleep. Science, 1961, 133, 1485-1486.
2. Hammack, J. T. An experimental analysis of behavior during sleep. U. S. Army Medical Research and Development Command, Annual Progress Report, January, 1962.
3. Hawkins, D. R., Puryear, H. B., Wallace, C. D., Deal, W. B., & Thomas, E. S. Basal skin resistance during sleep and "dreaming." Science, 1962, 136, 321-322.

Distribution.

15 copies	Commanding General U. S. Army Medical Research & Development Command Room 2537, Main Navy Building Washington 25, D. C.
10 copies	Armed Services Technical Information Agency Arlington Hall Station Arlington 12, Virginia
1 copy	Commanding Officer USAMEDS Combat Development Group Brooke Army Medical Center Fort Sam Houston, Texas